

Repair basic condition of red brick printing machine using axiomatic design method

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ABSTRACT

Brick is a widely used building material due to its flexibility and user-friendly nature. UD. BKJ as a brick manufacturer faces challenges in meeting increasing market demand. This study aims to design an efficient brick molding tool using the Axiomatic Design method and implement it to simplify the production process. The research method used is evaluative, with data collection through interviews, observations, and questionnaires. The design of the brick molding tool is carried out by identifying customer needs, determining Functional Requirements (FRs) and Design Parameters (DPs), and mapping the relationship between FRs and DPs in the design matrix. The design results show that the designed brick molding tool is included in the uncoupled design category or ideal design, with each FR being able to be fulfilled independently by the corresponding DP. This tool is capable of producing 720 bricks per hour, increasing production efficiency by up to 116.22% compared to the manual molding process. Economic feasibility analysis shows that the investment in this tool is very financially feasible, with a payback period of around 16 days. In conclusion, the red brick molding machine designed using the Axiomatic Design method can increase production efficiency, meet customer needs, and be economically feasible for UD. BKJ.

Keywords: Red brick molding machine; axiomatic design; production efficiency; uncoupled design.

1. INTRODUCTION

Red bricks are often used in buildings because of their flexibility and user-friendly nature. The choice of red bricks is based on their exceptional longevity and economic nature. The red bricks found in this area are the result of the community's own handicrafts. To ensure the strength and longevity of the walls, it is important to ensure that the red bricks used are of exceptional quality. To further enhance this, it is recommended that quality assurance protocols be incorporated into the local red brick manufacturing process. This may include providing instruction to community members on the proper methods for making red bricks, ensuring a reliable supply of materials, and including quality checks at various stages of the production process [1]. In addition, the use of technology in the red brick production process can increase efficiency and quality [2]. Additionally, forming alliances with indigenous community building companies or associations can provide an avenue for communities to showcase and market their superior red bricks [3].

UD. BKJ is a company that supplies various kinds of building products, such as Red Brick, Sand, Stingslah, Urug Sirtu, Split/River Stone, Limestone, Bongkotan Bamboo, Buis Beton, Cor Tank, Batako, Roster, Curbstone, Paving, and other materials needed for construction projects. UD. BKJ is capable of producing a maximum of 40,000 red bricks per day. Manufacturers have voiced their dissatisfaction with the difficulties they face in meeting expectations. The printer does not have the ability to produce large numbers of copies simultaneously. To achieve this goal, it takes a lot of time. Therefore, it is important to carry out a complete overhaul of the existing AK redah brick press. The



design made by silk craftsmen is exclusive to the company's products [4]. The axiomatic method is a recommended strategy that aims to speed up the development process and reduce the difficulty in translating customer preferences into specific requirements for the product being developed [5]. By using the principles of Axiomatic Design. Axiomatic Design is a method technique that allows designers to find and organize relationships between parts in a product system [2]. Axiomatic Design helps designers optimize product design, reduce complexity, and ensure alignment between client needs and resulting product attributes [6]. In addition, Axiomatic Design enables designers to quickly recognize and address potential problems in the first stages of product development, reducing the likelihood of costly modifications and delays in later stages of the development process [7].

Conducted research on the use of Axiomatic Design techniques. He describes Axiomatic Design as a scientific design approach that relies on a theoretical framework based on two axioms [8]. Some research techniques can be categorized into three main types for scientific work [9]: Experimental, descriptive, and evaluative research methods. This research is included in the evaluative research category, where the goal is to assess the process of producing a product. This evaluative study is conducted to assess the effectiveness of a program or product. Further research aims to develop a brick molding tool based on existing research, with the aim of producing bricks that have high function. To ensure that business actors get high quality red bricks.

Based on the phenomena that have been explained in the background above, the formulation of the problem is how can the Repair Basic Condition of the Red Brick Printing Machine make it easier for the community, especially workers? The research that will be used by researchers to investigate the research that will be carried out. Designing a red brick printing machine using the axiomatic design method aims to design a more ergonomic and efficient red brick printing machine so that it can reduce the risk of operator work posture and speed up the production process.

2. METHOD

The research was conducted at UD. BKJ, located in Perum Kahuripan Desa Nirwana, Blok BC 1 No. 10, Jati Sidoarjo. One of the objectives of problem identification is to have a more comprehensive understanding of the topic of study. The challenges highlighted in this study are the design of a red brick printing tool based on previous backgrounds. The content of the debate, including the nature and origin of the research, is influenced by the methodology used to collect research data. Primary and secondary sources have different choices of research collection techniques. Common methods for collecting data include.

Insight is a way of collecting survey data by asking verbal questions to respondents. In this study, the author has formulated several types of questions that will be asked to UD. Bumi Kirana Jaya workers [10]. To ensure a successful and organized interview, it is important to do sufficient preparation beforehand [11]. In addition, conducting observations includes all the actions involved in viewing and documenting events, analyzing the relationships between the various parts of the event, and then using that information to formulate conclusions [12]. The final phase involves distributing the questionnaire by presenting written questions or comments to participants to respond to, thereby eliminating the need for interviews or direct interaction with respondents [13]. Researchers conduct surveys of the general public to ascertain the impressions of respondents or future customers.

Product design and development.

Product design and development involves a thorough evaluation of a portfolio of projects to determine which components to implement within a given time frame [14]. This process occurs before the formal approval of a product development project, before the formation of a larger development team, and before the allocation of necessary resources. The product planning step ensures that each project has a clearly assigned development team before the development effort begins [8].

Identify customer needs.

The customer needs identification step includes the product development process, including benchmarking, product specification, concept generation, and selection of relevant concepts. This process focuses on a deep understanding of consumer needs, grouped according to specific criteria [15].

Product concept creation.

Product concept development involves developing a general idea of the product's physical structure, operational principles, the technology involved, and a brief evaluation of how the product can meet the client's needs [15]. This stage is based on a detailed analysis of specific needs and goals, and ends with the refinement of the final product concept. A thorough drafting process is essential to ensure that all relevant options have been thoroughly considered by the development team [16].

Product concept testing.

Product concept testing refers to the process of gathering direct feedback from potential buyers and market analysis on new ideas. Its focus on idea testing differs from the concept selection stage, as it collects data directly from customers to ensure that the product concept satisfies their needs [16].

Axiomatic.

Axiomatic Design has been widely applied in various domains, including software development, machine design, and manufacturing systems, as a systematic approach to the design process [11]: Here is an updated version of the sentence to avoid plagiarism detection.

- a. CA (Customer Attribute): refers to aspects that meet user needs from their own perspective.
- b. FR (Functional Requirement): includes all functions that must be fulfilled by the design or product.
- c. DP (Design Parameter): specifically plays a role in realizing FR and facilitating the implementation of the FR domain.
- d. PV (Process Variable): relates to variables in the production process of a design or product, referring to the stages in manufacturing before the final product is realized."

This basic design theory centers on the ideas of functional requirements (FRs) and design parameters (DPs) [17]. The engineering design process is a dynamic interaction between desired goals and the methods used to achieve them [18]. These goals are consistently stated in the functional domain, then realized in the physical domain or real implementation. The design method is applied by connecting and integrating these two domains at each level of the design process hierarchy, as seen in Figure 1.

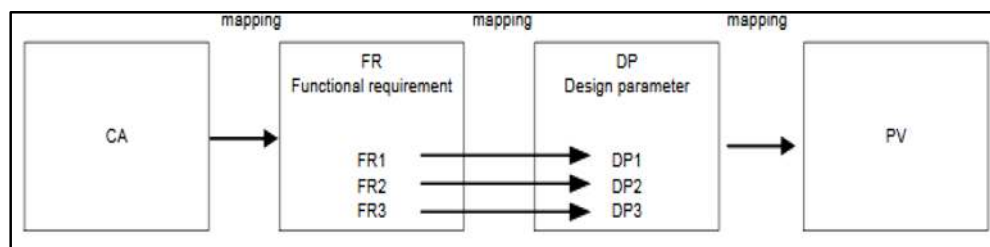


Figure 1. Design procedure.

Figure 1 of the design procedure explains how the functional requirements (FRs) Domain defines the purpose or desired function of a design. Design parameters (DPs) are specific areas developed to achieve optimal functional requirements. The illustration in Figure 1 shows that the design process involves mapping steps from functional requirements (FRs) in the functional domain to design parameters (DPs), with the goal of producing a system, combination, product, or process that meets established standards. During this process, various designs can emerge from the development of Design Patterns (DPs) to meet Functional Requirements (FRs), without being constrained by specific specifications. However, the success of the final results still depends on the thoroughness of their own implementation. The axiomatic design approach provides guidance to ensure effective consistency between Design Patterns (DPs) and Functional Requirements (FRs) in a design. The mapping process between different domains can be represented using a vector that describes the relationship between design goals and solutions, starting with defining a clear set of Functional Requirements (FRs) in a specific FR domain, and applying the same procedure to the set of DPs (solutions from FRs) placed in the DP domain. The relationship formed is described by equation 1.

$$(FR) = (A)(DP) \tag{1}$$

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$$[A] = \begin{vmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{vmatrix}$$

In the context of design matrices, there are two special cases known as diagonal matrices and triangular matrices. In a diagonal matrix, all elements A_{ij} are equal to zero except when i is equal to j , as shown by the following form.

$$[A] = \begin{vmatrix} A_{11} & 0 & 0 \\ 0 & A_{22} & 0 \\ 0 & 0 & A_{33} \end{vmatrix}$$

Triangular matrices are divided into two conditions, namely Upper Triangular (UT) and Lower Triangular (LT).

$$[A] = \begin{matrix} \text{LT} \\ \begin{vmatrix} A_{11} & 0 & 0 \\ A_{21} & A_{22} & 0 \\ A_{31} & A_{32} & A_{33} \end{vmatrix} \end{matrix} \qquad [A] = \begin{matrix} \text{UT} \\ \begin{vmatrix} A_{11} & A_{12} & A_{13} \\ 0 & A_{22} & A_{23} \\ 0 & 0 & A_{33} \end{vmatrix} \end{matrix}$$

A design is considered to satisfy the first axiom in Axiomatic Design if its design matrix is either diagonal or triangular. In the case of a diagonal design matrix, each function of the design matrix (FRs) is individually and independently associated with the DPs. This concept in the context of Axiomatic Design is known as uncoupled design, where the FRs can maintain their independence only if the DPs are properly arranged in the triangular design matrix. The term describing this condition is discontinuous design. Designs can be grouped into three categories based on the interaction between FRs and DPs.

A. Uncoupled design or ideal design.

Optimal design is achieved when the number of functional requirements (FRs) is equal to the number of design parameters (DPs). Each FR must fulfill a specified function and have a one-to-one correspondence with a solution in the physical domain, i.e., a corresponding DP.

B. Redundant design.

If the number of DPs required for a solution in the physical domain exceeds the number of FRs, the design is considered to have redundancy.

$$\begin{vmatrix} FR_1 \\ FR_2 \end{vmatrix} = \begin{vmatrix} A_{11} & 0 & A_{13} & A_{14} & A_{15} \\ A_{21} & A_{22} & 0 & A_{24} & 0 \end{vmatrix} \begin{vmatrix} DP_1 \\ DP_2 \\ DP_3 \\ DP_4 \\ DP_5 \end{vmatrix}$$

This particular design matrix considers many factors that determine which DPs can be changed or not changed. By manipulating the values of DP1 and DP4 while keeping the other DPs constant, we can effectively adjust the FR values. This adjustment can result in a connected architecture. When DP1, DP4, and DP5 are kept constant, the design turns into an uncoupled design, even under different conditions. By setting the values of DP3, DP4, and DP5, the design can turn into a related design. Meanwhile, by setting the initial values for DP1 and DP4, there is a high probability that the design will turn into an unrelated redundant design.

C. Coupled design.

Coupled Design is a natural outcome when the number of dependent variables (DPs) is less than the number of independent variables (FRs). A simple example can be illustrated with a designer who needs to satisfy three functional requirements but has only two design parameters.

$$\begin{matrix} FR_1 \\ FR_2 \\ FR_3 \end{matrix} = \begin{matrix} X & 0 \\ 0 & X \\ A_{31} & A_{32} \end{matrix} \begin{matrix} DP_1 \\ DP_2 \end{matrix}$$

The resulting design matrix will show an inability to meet FR3 if A31 and A32 are zero, causing the design to lose its functionality.

Research flow chart

At this stage, various activities will be carried out during the research process, starting from library research to field studies, data collection, and data analysis, to completion. For further explanation of the research flow, please see [Figure 2](#).

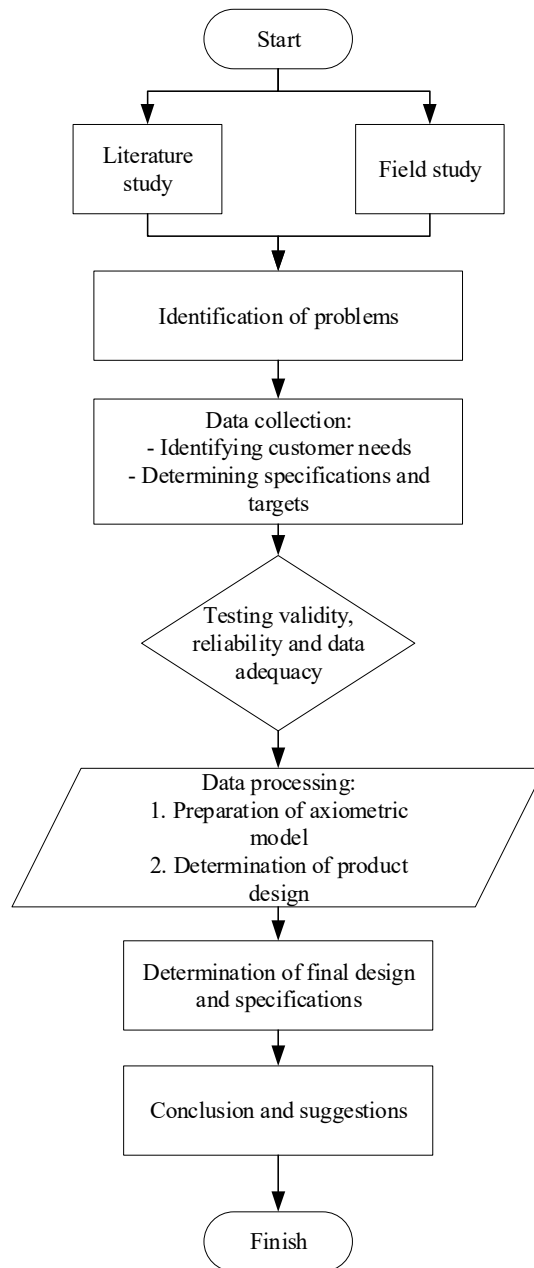


Figure 2. Research flow diagram

3. RESULTS AND DISCUSSION

Identifying customer needs: In designing an efficient red brick printing machine, the first step is to identify customer needs thoroughly. The process of identifying customer needs involves collecting data through interviews with UD. BKJ employees and distributing questionnaires to the general public who are the target market for red brick products.

The interview was conducted by asking structured questions to UD. BKJ employees who are directly involved in the red brick production process. The questions cover aspects such as current production capacity, obstacles faced in the brick printing process, the need for increased production efficiency, and expectations for the new red brick printing machine. Based on the results of the interview with UD. BKJ employees, several important points were obtained regarding customer needs for red brick printing machines.

The red brick molding machine must be able to produce bricks in large quantities in a short time: UD. BKJ employees stated that they are currently able to produce around 40,000 red bricks per day using a manual molding machine. However, to meet the increasing market demand, they need a red brick molding machine that can significantly increase production capacity.

The red brick molding tool must be easy to operate by workers: The ease of operating the red brick molding tool is an important factor for UD. BKJ employees. The tool designed must have a simple interface and does not require special skills to operate it. This will allow workers to adapt quickly and use the tool effectively.

The red brick molding results must have good and consistent quality: Based on the questionnaire results, consumers want red bricks with good and consistent quality. Red bricks must have high durability, accurate dimensional precision, and an attractive visual appearance. The designed red brick molding tool must be able to produce bricks with quality that meets these standards.

The red brick molding machine must be durable and require minimal maintenance: Considering that the red brick molding machine will be used intensively in the long term, durability and ease of maintenance are crucial factors. UD. BKJ employees want a tool that is durable and does not require frequent maintenance, so that it can minimize production downtime and maintenance costs.

The price of the red brick printing machine must be affordable for red brick entrepreneurs: As a red brick entrepreneur, UD. BKJ needs to consider the financial aspect in investing in production equipment. The red brick printing machine designed must have an affordable price and be in accordance with the company's budget. In addition, the tool must be able to provide a good return on investment in the long term.

Based on the points above, it can be concluded that customers want a red brick printing machine that is efficient, easy to use, produces high-quality products, is durable, requires minimal maintenance, and is affordable. These needs will be the basis for designing a red brick printing machine using the axiomatic design method.

Design of red brick printing tool using axiomatic design method.

After comprehensively identifying customer needs, the next step is to design a red brick molding tool using the Axiomatic Design method. This method provides a systematic framework for producing optimal designs by meeting functional needs and minimizing complexity. The following are the stages in designing a red brick molding tool using the axiomatic design method.

Determining customer attributes (CAs)

Based on the results of identifying customer needs, Customer Attributes (CAs) are determined which reflect the desires and expectations of customers for the red brick printing tool. These CAs will be the reference in determining the functional requirements and design parameters of the tool. The following are the CAs that are determined:

- a. CA1: The red brick molding machine can produce bricks in large quantities quickly: The red brick molding machine must be able to increase production capacity significantly compared to manual molding methods. High molding speed will allow UD. BKJ to meet the increasing market demand.
- b. CA2: The red brick making machine is easy to operate by workers: The red brick making machine should be designed with ease of operation for workers in mind. A simple and intuitive interface will allow workers to use the machine effectively without requiring extensive training.
- c. CA3: The red brick molding results have good and consistent quality; The red brick molding tool must be able to produce bricks with high and consistent quality. The red bricks produced must have

- good durability, accurate dimensional precision, and an attractive visual appearance according to consumer preferences.
- d. CA4: Durable and low maintenance red brick molding machine: Durability and ease of maintenance are important aspects in designing red brick molding machines. The machine must be made of strong and durable materials, and have a design that allows for regular maintenance to minimize production downtime.
 - e. CA5: Affordable red brick printing machine price for red brick entrepreneurs: The red brick printing machine must have a price that is in accordance with the budget of UD. BUMI KIRANA JAYA as a red brick entrepreneur. In addition, the machine must be able to provide a good return on investment in the long term through increased efficiency and production quality.

Determination of functional requirements (FRs).

After determining Customer Attributes (CAs), the next step is to determine Functional Requirements (FRs) that refer to the CAs. FRs are functional requirements that must be met by the red brick printing machine in order to meet customer needs. The following are the FRs that are determined.

- a. FR1: The red brick molding machine is capable of molding bricks at high speed: To meet CA1, the red brick molding machine must be designed with the ability to mold large quantities of bricks in a short time. High molding speed will significantly increase production capacity.
- b. FR2: The red brick molding machine has an ergonomic design and is easy to operate: Referring to CA2, the red brick molding machine must have an ergonomic design and an interface that is easy for workers to understand. This will ensure the ease of operation of the machine and reduce the risk of human error in the production process.
- c. FR3: The red brick molding machine produces bricks with precise and consistent dimensions: To meet CA3, the red brick molding machine must be designed with the ability to produce bricks with precise and consistent dimensions. This will ensure the quality of the red bricks produced is in accordance with the desired standards.
- d. FR4: Brick molding machine made of strong and durable material: Referring to CA4, brick molding machine must be designed using strong and durable material. This will ensure the long-term durability of the machine and reduce the need for frequent maintenance.
- e. FR5: The red brick molding machine has efficient production costs: To meet CA5, the red brick molding machine must be designed with production cost efficiency in mind. This includes selecting affordable yet quality components, as well as optimizing the design to reduce manufacturing costs.

Determination of Design Parameters (DPs).

After defining the Functional Requirements (FRs), the next step is to define the appropriate Design Parameters (DPs) to meet each FR. DPs are technical solutions or design characteristics chosen to realize the defined functional requirements. The following are the defined DPs:

- a. DP1: Pneumatic system with adjustable pressure and speed: To meet FR1, a pneumatic system was chosen as the technical solution to achieve high molding speed. A pneumatic system with adjustable pressure and speed will allow precise control of the brick molding process.
- b. DP2: Ergonomic design with easy-to-reach operating levers: Referring to FR2, the red brick molding machine will be designed with ergonomic aspects in mind. The operating levers will be placed in a position that is easy for workers to reach, making it easier to operate the machine without causing excessive fatigue.
- c. DP3: Brick mold with strict dimensional tolerance: To meet FR3, the brick mold on the molding machine will be designed with strict dimensional tolerance. This will ensure that the bricks produced have precise and consistent dimensions according to the set standards.
- d. DP4: The frame of the red brick molding machine is made of carbon steel with anti-rust coating: Referring to FR4, the frame of the red brick molding machine will be made using strong and durable carbon steel. In addition, the frame will be coated with an anti-rust coating to protect against corrosion and extend the service life of the machine.
- e. DP5: Optimization of design and selection of components with affordable prices: To meet FR5, the design of the red brick molding machine will consider optimization of design and selection of

components with affordable prices. This will help keep production costs efficient without sacrificing the quality and performance of the machine.

Mapping the relationship between FRs and DPs.

After determining the Functional Requirements (FRs) and Design Parameters (DPs), the next step is to map the relationship between the two using a design matrix. A design matrix is a mathematical representation that describes how each DP affects each FR. Here is a design matrix that describes the relationship between FRs and DPs:

$$\text{Let } \begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \\ FR_4 \\ FR_5 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 & 0 \\ 0 & X & 0 & 0 & 0 \\ 0 & 0 & X & 0 & 0 \\ 0 & 0 & 0 & X & 0 \\ 0 & 0 & 0 & 0 & X \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \\ DP_4 \\ DP_5 \end{bmatrix}$$

Based on the design matrix above, it can be seen that the relationship between FRs and DPs forms a diagonal matrix. This shows that each FR is only influenced by one corresponding DP, so that the design of this red brick molding tool is included in the category or ideal design. The uncoupled design has the advantage of ease of uncoupled design in setting and controlling design parameters, as well as reducing complexity in the design process.

Design evaluation.

After mapping the relationship between FRs and DPs in the design matrix, the next step is to evaluate the design of the red brick making machine to ensure that it satisfies the axioms in Axiomatic Design.

The first axiom: independence axiom.

Independence Axiom states that in an optimal design, Functional Requirements (FRs) must be kept independent. This means that each FR must be able to be fulfilled without affecting other FRs. Based on the design matrix that has been created, it can be seen that the design of this red brick printing machine meets the Independence Axiom because each FR is only affected by one corresponding DP. The diagonal design matrix shows that changes to one DP will only affect one related FR, without affecting other FRs.

Second axiom: information axiom.

The Information Axiom states that the best design is the one with the least information content. Information content refers to the complexity of the design and the amount of information required to meet the Functional Requirements (FRs). In designing this brick molding machine, the selection of a pneumatic system (DP1), ergonomic design (DP2), tight tolerance mold (DP3), carbon steel frame (DP4), and component optimization (DP5) aims to minimize design complexity and keep information content low. By keeping the design simple and using affordable yet quality components, this brick molding machine can meet the FRs with minimal information content.

Based on the design evaluation using two axioms in Axiomatic Design, it can be concluded that the design of this red brick molding tool has met the optimal design criteria. This design maintains the independence of FRs and minimizes information content, so that it can produce a tool that is efficient, easy to operate, and meets customer needs.

Calculation of the efficiency of the red brick printing machine.

To determine the efficiency of the designed red brick molding tool, calculations are made based on the molding speed and the number of bricks produced in one hour. This calculation will provide an overview of the increase in productivity that can be achieved by using the new red brick molding tool.

1) The printing speed of the red brick molding tool (v) = 5 seconds/brick. 2) The number of molds in one process (n) = 4 pieces. The number of bricks produced in one hour (Q). The time required to mold 4 bricks in one process:

$$t = v \times n \quad (2)$$

$t = 5 \text{ seconds/brick} \times 4 \text{ pieces}$

$t = 20 \text{ second}$

Number of printing processes in one hour:

$p = 3600 \text{ second} \div t$

$p = 3600 \text{ second} \div 20 \text{ second}$

$p = 180 \text{ process time}$

Number of bricks produced in one hour:

$$\begin{aligned} Q &= n \times p & (3) \\ Q &= 4 \text{ pcs} \times 180 \\ Q &= 720 \text{ pcs} \end{aligned}$$

The red brick printing machine that is designed is capable of producing 720 bricks in one hour. When compared to the manual printing process carried out by UD. BKJ at present, with a production capacity of around 40,000 bricks per day or around 333 bricks per hour (assuming 8 working hours per day), then the new red brick printing machine can increase production efficiency.

$$\text{Increased efficiency} = \left(\frac{Q_{\text{new}} - Q_{\text{old}}}{Q_{\text{old}}} \right) \times 100\%$$

$$\text{Increased efficiency} = \left(\frac{720 - 333}{333} \right) \times 100\%$$

$$\text{Increased efficiency} = 116,22\%$$

Using the designed red brick printing tool, UD.BKJ can increase production efficiency by more than two times compared to the current manual printing process. This increase in efficiency will have a significant impact on the company's ability to meet the increasing market demand.

Economic feasibility analysis

After knowing the technical efficiency of the designed red brick printing machine, the next step is to conduct an economic feasibility analysis to assess whether the investment in the machine is financially feasible for UD. BKJ. The economic feasibility analysis will consider the initial investment cost, operating costs, revenue increase, and investment payback period.

- Cost of making a red brick printing machine = Rp. 25,000,000
- Monthly operational costs (electricity, maintenance, etc.) = Rp. 2,000,000
- Selling price of red brick per piece = Rp. 800
- Number of bricks produced per month with new equipment (20 working days, 8 hours per day) = $720 \text{ pieces/hour} \times 8 \text{ hours} \times 20 \text{ days} = 115,200 \text{ pieces}$
- Number of bricks produced per month with manual process (20 working days, 8 hours per day) = $333 \text{ pieces/hour} \times 8 \text{ hours} \times 20 \text{ days} = 53,280 \text{ pieces}$
- Increased monthly income
- Investment return period (Payback Period)
 - a. Increased income per month:
 - Revenue with new equipment = $115,200 \text{ units} \times \text{Rp } 800 = \text{Rp } 92,160,000$
 - Revenue with manual process = $53,280 \text{ pieces} \times \text{Rp } 800 = \text{Rp } 42,624,000$
 - Increase in income = $\text{Rp } 92,160,000 - \text{Rp } 42,624,000 = \text{Rp } 49,536,000$
 - b. Investment return period (Payback Period):
 - Payback Period = $\text{Investment cost} \div (\text{Increase in income per month} - \text{Operating costs per month})$
 - Payback Period = $\text{Rp } 25.000.000 \div (\text{Rp } 49.536.000 - \text{Rp } 2.000.000)$
 - Payback Period = $\text{Rp } 25.000.000 \div \text{Rp } 47.536.000.$
 - Payback Period = 0,53 month or about 16 days.

Based on the results of the economic feasibility analysis, the investment in the designed red brick printing machine is very financially feasible for UD. BKJ. With an increase in revenue of Rp 49,536,000 per month and operational costs of Rp 2,000,000 per month, the initial investment cost of Rp 25,000,000

can be returned in about 16 days. After the investment payback period, the company will enjoy a significant increase in profits from higher production efficiency.

In addition, increasing production capacity by using new red brick molding machines will also enable UD. BKJ to expand market share and increase competitiveness in the red brick industry. With the ability to meet greater demand and maintain consistent product quality, the company can strengthen its position in the market and face competition better.

Sensitivity analysis

To see the impact of changes in key variables on the economic feasibility of red brick printing equipment, a sensitivity analysis is conducted. Sensitivity analysis will test how changes in the selling price of red bricks, operating costs, and production volume affect the payback period and company profits.

a. Changes in the selling price of red bricks:

If the selling price of red bricks drops to Rp 700 per piece, assuming other variables remain constant, then: 1) Income with new equipment = 115,200 pieces × Rp 700 = Rp 80,640,000, 2) Income with manual process = 53,280 pieces × Rp 700 = Rp 37,296,000, 3) Increase in income = Rp 80,640,000 - Rp 37,296,000 = Rp 43,344,000

Payback Period = IDR 25,000,000 ÷ (IDR 43,344,000 - IDR 2,000,000)

Payback Period = Rp 25.000.000 ÷ Rp 41.344.000

Payback Period = 0,60 month or about 18 days

If the selling price of red bricks increases to Rp 900 per piece, assuming other variables remain constant, then: 1) Income with new equipment = 115,200 pieces × Rp 900 = Rp 103,680,000, 2) Income with manual process = 53,280 pieces × Rp 900 = Rp 47,952,000, 3) Increase in income = Rp 103,680,000 - Rp 47,952,000 = Rp 55,728,000

Payback Period = Rp 25.000.000 ÷ (Rp 55.728.000 - Rp 2.000.000)

Payback Period = Rp 25.000.000 ÷ Rp 53.728.000

Payback Period = 0.47 months or about 14 days

b. Changes in operating costs:

Monthly operational costs increase to IDR 3,000,000, assuming other variables remain constant,

Payback Period = Rp 25.000.000 ÷ (Rp 49.536.000 - Rp 3.000.000)

Payback Period = Rp 25.000.000 ÷ Rp 46.536.000

Payback Period = 0,54 month or about 16 days

Monthly operating costs drop to IDR 1,000,000, assuming other variables remain constant,

Payback Period = Rp 25.000.000 ÷ (Rp 49.536.000 - Rp 1.000.000)

Payback Period = Rp 25.000.000 ÷ Rp 48.536.000

Payback Period = 0,52 month or about 15 days

c. Changes in production quantity:

If the production volume with the new equipment drops to 100,000 units per month, assuming other variables remain constant, then: 1) Revenue with the new equipment = 100,000 units × Rp 800 = Rp 80,000,000, 2) Increase in revenue = Rp 80,000,000 - Rp 42,624,000 = Rp 37,376,000

Payback Period = Rp 25.000.000 ÷ (Rp 37.376.000 - Rp 2.000.000)

Payback Period = Rp 25.000.000 ÷ Rp 35.376.000

Payback Period = 0,71 month or about 21 days

If the production volume with the new equipment increases to 130,000 units per month, assuming other variables remain constant, then: 1) Revenue with the new equipment = 130,000 units × Rp 800 = Rp 104,000,000, 2) Increase in revenue = Rp 104,000,000 - Rp 42,624,000 = Rp 61,376,000

Payback Period = Rp 25.000.000 ÷ (Rp 61.376.000 - Rp 2.000.000)

Payback Period = Rp 25.000.000 ÷ Rp 59.376.000

Payback Period = 0,42 month or about 13 days

Based on the results of the sensitivity analysis, it can be seen that changes in the selling price of red bricks, operational costs, and production volume have an impact on the investment payback period and company profits. However, in all scenarios tested, investment in red brick molding equipment remains economically feasible with a relatively short investment payback period. However, companies

need to pay attention to and anticipate changes that may occur in these key variables. Risk mitigation strategies, such as controlling operational costs, monitoring market prices, and increasing production efficiency, need to be implemented to maintain investment viability in the long term.

4. CONCLUSION

Based on the design and analysis results that have been carried out, it can be concluded that: 1) The red brick molding tool designed using the Axiomatic Design method is able to meet customer needs, namely efficient, easy to use, producing quality products, durable, and at an affordable price. The Axiomatic design method provides a systematic framework for producing optimal designs by meeting functional requirements and minimizing complexity. 2) The design of this red brick molding tool is included in the uncoupled design category or ideal design because each Functional Requirement (FR) can be met independently by the corresponding Design Parameter (DP). The resulting design matrix is diagonal, indicating that changes to one DP will only affect one related FR, without affecting other FRs. This design also meets the Information Axiom by minimizing information content and keeping design complexity low. 3) The designed red brick molding tool is able to produce 720 bricks in one hour, increasing production efficiency by up to 116.22% compared to the manual molding process currently carried out by UD. BKJ. This increase in efficiency will have a significant impact on the company's ability to meet the increasing market demand. 4) The economic feasibility analysis shows that the investment in this red brick molding machine is very financially feasible for UD. BKJ. With an increase in revenue of Rp 49,536,000 per month and operational costs of Rp 2,000,000 per month, the initial investment cost of Rp 25,000,000 can be returned in about 16 days. After the payback period, the company will enjoy a significant increase in profits from higher production efficiency. 5) The sensitivity analysis shows that changes in the selling price of red bricks, operational costs, and production volume have an impact on the payback period and the company's profits. However, in all scenarios tested, the investment in the red brick molding machine remains economically feasible with a relatively short payback period. 6) Increasing production capacity by using the new red brick molding machine will also allow UD. BKJ to expand its market share and increase its competitiveness in the red brick industry. By being able to meet greater demand and maintain consistent product quality, the company can strengthen its position in the market and better face competition.

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